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REFRIGERATION HEAT RECLAIM

MANCO DAIRY
DAUPHIN, MANITOBA

MC NUMBER 13255

83.181
MARCH 1985

MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources — oil and natural gas — are becoming less accessible and more costly. However, Canada is well-endowed with renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminated March 31, 1984. The Agreement was dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program had a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

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TABLE OF CONTENTS

LIST OF FIGURES, TABLES, & PHOTOGRAPHS.....ii

EXECUTIVE SUMMARY..... 1

INTRODUCTION..... 3

OPERATION OF A REFRIGERATION SYSTEM
- GENERAL DESCRIPTION..... 4

THE ORIGINAL & THE MODIFIED REFRIGERATION
SYSTEMS AT MANCO..... 6

OPERATION OF THE MODIFIED SYSTEM..... 9

ECONOMIC ANALYSIS OF SYSTEM MODIFICATIONS.....12

CONCLUSIONS AND RECOMMENDATIONS.....14

TABLES & PHOTOGRAPHS.....16

LIST OF FIGURES, TABLES, & PHOTOGRAPHS

FIGURE 1. Simplified Refrigeration System..... 5

FIGURE 2. Original Refrigeration System
- Simplified Schematic..... 8

FIGURE 3. Modified Refrigeration System.....10

TABLE 1. Cost of Refrigeration System Modifications...16

TABLE 2. Calculation of Estimated Energy Savings.....17

PHOTO 1. Compressor.....18

PHOTO 2. 3-Way Valve & Head Pressure Regulator Valve.19

PHOTO 3. Shipping/Receiving Area.....20

PHOTO 4. Heat Reclaim Coil and Fan.....21

PHOTO 5. Check Valve For Heat Reclaim Unit.....22

PHOTO 6. Roof Top Air-Cooled Condenser.....23

EXECUTIVE SUMMARY

Manco Dairy, a standard dairy operation, has modified its refrigeration systems to allow heat reclaim for space heating and to eliminate the cost of condenser cooling water.

The objectives of this project are to demonstrate and verify:

1. energy savings from refrigeration heat reclaim, and
2. savings in water consumption through the replacement of the water-cooled condensers with an air-cooled condenser.

During the construction phase of the project, Intract Consultants of Winnipeg gathered relevant technical and cost data through site inspections, conversations with Manco staff and the installers, utility information, and other independent sources.

Modifications were completed in February 1985, and data verification and analysis followed. Cost/benefit analysis of the project showed that:

1. energy savings from refrigeration heat reclaim are estimated to be $2 100 per year, while
2. savings in water consumption are $5 200 per year, for a total annual savings of $7 300. With the system modifications costing $16 565, this project yields a simple payback of 2.3 years.

Additional savings are expected from the reduction in operating and maintenance cost due to the elimination of pressure regulating water valves and also due to the reduced compressor head pressure. However, savings in operating and maintenance cost are not included in this report as the modified system has not been in operation for a sufficient period of time to allow an estimate of these savings.

Another benefit from the modified system is the shorter period of time for refrigerated space to reach the desired temperature.

This project has successfully demonstrated that refrigeration heat reclaim techniques and conversion of condensers from water-cooled to air-cooled both save money, and when combined provide very attractive returns on investment.

RÉSUMÉ ADMINISTRATIF

La compagnie "Manco Dairy", une laiterie de modèle standard, a modifié son système frigorifique afin de récupérer la chaleur émise pour chauffer les bâtiments et éliminer le coût de l'eau de refroidissement des condenseurs.

Les objectifs de ce projet sont de démontrer et de vérifier ce qui suit :

1. l'économie d'énergie découlant de la récupération de la chaleur du système frigorifique.
2. l'économie de consommation d'eau réalisée en substituant l'air à l'eau comme agent de refroidissement des condenseurs.

Au cours des travaux de réalisation du projet, la firme d'experts-conseil "Intract Consultants" de Winnipeg a recueilli des données sur les coûts et les divers aspects techniques du projet en procédant à des inspections sur les lieux, en s'entretenant avec le personnel de "Manco-Dairy" et avec les ouvriers chargés des travaux et aussi en se renseignant auprès des entreprises de service public et d'autres sources indépendantes.

Terminés en février 1985, les travaux de transformation furent suivis de la vérification et de l'analyse des données. L'analyse coûts-rendements a démontré que :

1. l'économie d'énergie découlant de la récupération de la chaleur du système frigorifique est évaluée à 2 100 $ par an;
2. l'économie de consommation d'eau se chiffre à 5 200 $ par an, ce qui donne une économie globale de 7 300 $ par an. La période simple de récupération est donc de 2,3 ans puisque le coût des travaux de transformation a été de 16 565 $.

On prévoit réaliser d'autres économies grâce à la diminution des frais d'exploitation et d'entretien résultant de l'élimination des soupapes régulatrices de pression d'eau et de la baisse de pression à l'entrée des compresseurs. Toutefois, les économies touchant les frais d'exploitation et d'entretien n'ont pas été incluses dans le rapport car le système ne fonctionne pas depuis assez longtemps pour qu'on puisse évaluer de telles économies.

Enfin, le système modifié présente aussi l'avantage d'abaisser plus rapidement la température du compartiment à réfrigérer.

Grâce à ce projet, on a pu démontrer qu'il est profitable de recourir à la technique de récupération thermique et d'utiliser l'air plutôt que l'eau comme agent de refroidissement des condenseurs. En combinant les deux méthodes, on peut obtenir un bon rendement du capital investi.

INTRODUCTION

Manco Dairy in Dauphin, Manitoba is a standard dairy operation which uses refrigeration systems for cooling dairy products.

In late 1983, Manco applied for funding through the Manitoba/Canada Conservation and Renewable Energy Demonstration Agreement (CREDA) to modify its existing refrigeration systems to conserve and use energy efficiently. Funding was subsequently approved and the project was completed in February, 1985.

Intract Consultants, a Winnipeg engineering consulting firm, was engaged to monitor and evaluate this project.

The objectives of this project are to demonstrate and verify:

1. the energy savings possible in a refrigeration system through waste heat recovery techniques, and
2. the savings in water consumption through replacement of the water-cooled condensers with an air-cooled condenser.

OPERATION OF A REFRIGERATION SYSTEM - GENERAL DESCRIPTION

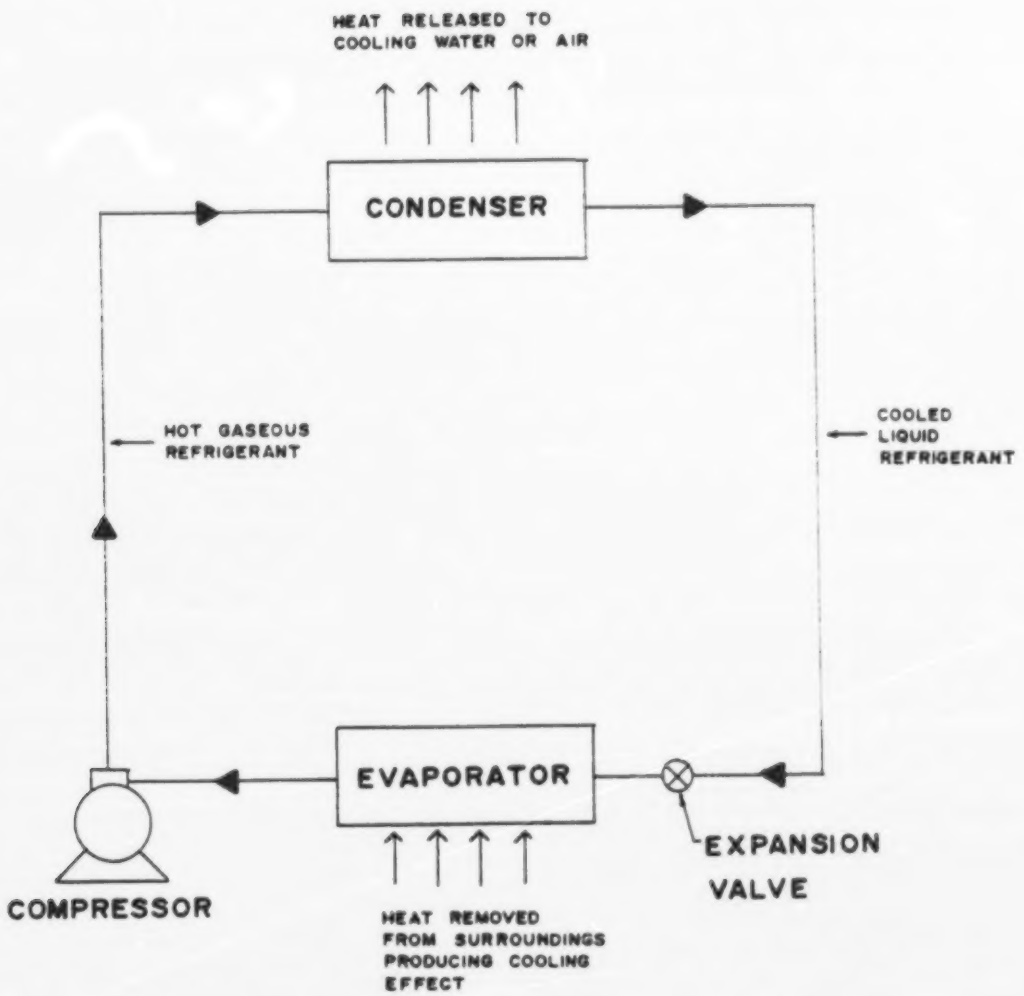
The major components of a typical refrigeration system are the evaporator, the compressor and the condenser. Refrigerant flows through these components through connecting pipes and control valves. A simplified refrigeration system circuit is shown in Figure 1. Its operation is as follows:

The refrigerant enters the evaporator in liquid form. It is allowed to expand and vaporize from a liquid to a gas within the evaporator which is kept at low pressure. As heat is required to transform the refrigerant from liquid to gas, it is absorbed by the refrigerant from the surroundings. The removal of heat from the surroundings produces the cooling effect.

The refrigerant leaves the evaporator as a low temperature low pressure gas. This gas is converted by the compressor to a high pressure, high temperature gas which is discharged to the condenser. At the condenser, heat is released through cooling water or air. The loss of heat from the high pressure, high temperature gas causes the refrigerant to condense back to liquid form at a lower temperature. The liquid refrigerant then circulates back to the evaporator through an expansion valve which lowers the pressure of the refrigerant. This completes the refrigeration cycle.

The rejected heat in a refrigeration cycle can be recovered or reclaimed by modifying the refrigeration system as discussed below:

FIGURE 1. SIMPLIFIED REFRIGERATION SYSTEM



THE ORIGINAL AND THE MODIFIED REFRIGERATION SYSTEMS AT MANCO

A schematic of the original refrigeration system is shown in Figure 2. For simplicity, only one individual refrigeration circuit is shown, although there are actually two circuits. The actual system consists of two 15hp compressors, two evaporators, two receivers and two water-cooled condensers. One of the refrigeration circuits uses R-12 refrigerant while the other circuit uses R-502 refrigerant with cooling capacities of 9.7 tons and 5 tons respectively.

The components of the modified system are shown in Photo 1 to 5. A schematic of the modified refrigeration system is shown in Fig. 3. As above, only one individual refrigeration circuit is shown. In the modified system, the two water-cooled condensers were replaced with one roof-top air-cooled condenser. This new air-cooled condenser contains two separate refrigeration circuits - one for the R-502 refrigerant and the other for the R-12 refrigerant. The cooling capacities of these new circuits are comparable to those of the circuits replaced.

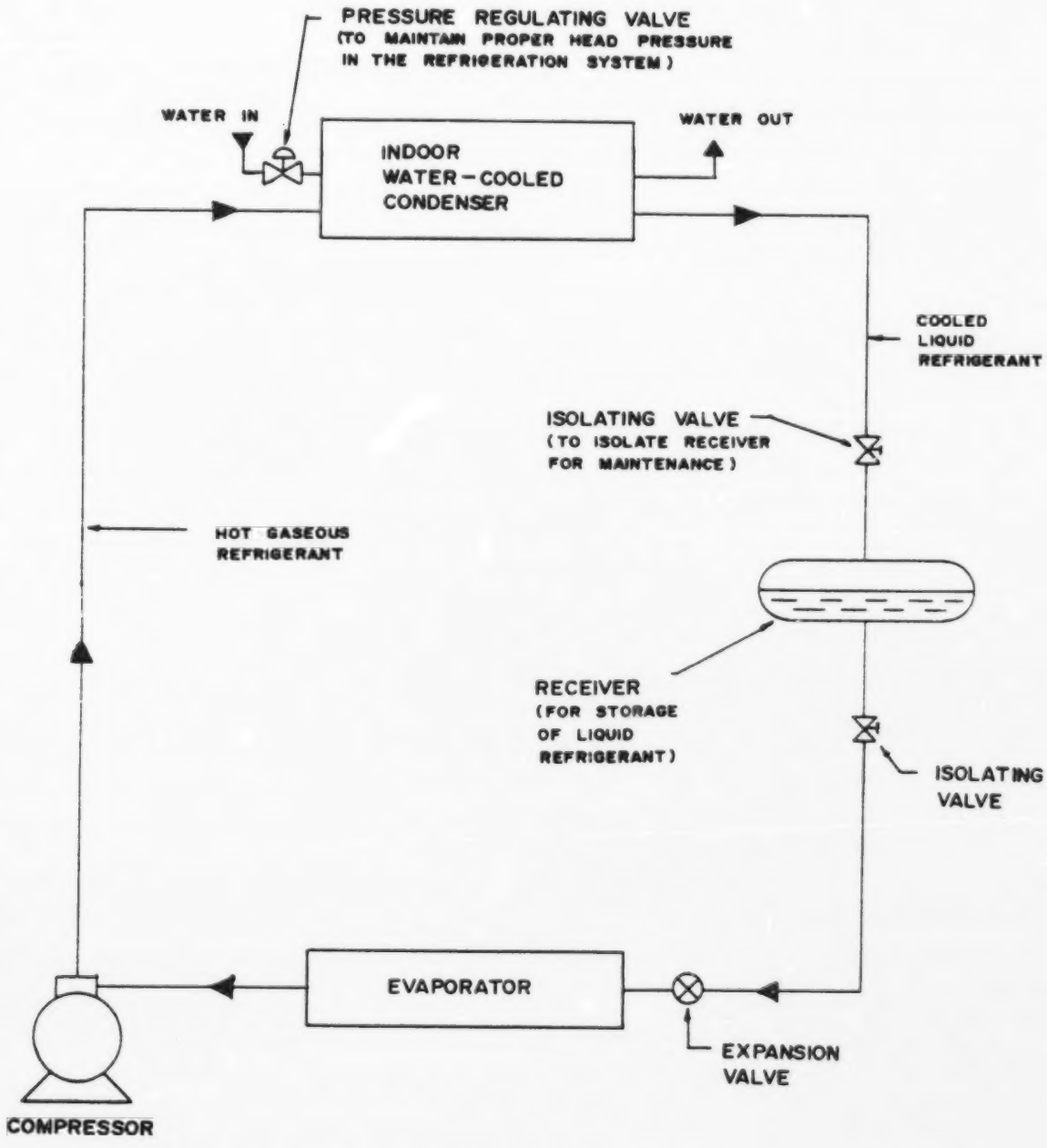
In addition, a new heat reclaim coil was installed in series between the compressor and the condenser in each refrigeration circuit. Part of the available heat that used to be released as waste heat by the condenser, is now captured by the reclaim coil and used for space heating. The operation of the heat reclaim coil is controlled by a 3-way valve and is described

in the next Section.

Furthermore, an ALLS valve was installed downline of the expansion valve to reduce electric power consumption. The ALLS valve is a patented system that allows the head pressure to follow the ambient temperature of the condenser. For every 5.5 degrees Celcius drop in condensing temperature, there is a 6% increase in compressor capacity and a corresponding 8% reduction in power consumption. Hence, the lower the compressor ambient, the greater the potential savings. The increased BTU/watt of the compressor reduces the operating expense of refrigeration.

A head-pressure regulating valve was also installed on the discharge line of the compressor to maintain proper head-pressure in this system. In the original system, this function was performed by the pressure-regulating water valve in the incoming water line of the water-cooled condenser. (See Fig. 2)

FIGURE 2. ORIGINAL REFRIGERATION SYSTEM SIMPLIFIED SCHEMATIC.



OPERATION OF THE MODIFIED SYSTEM

The principle of operation of the modified refrigeration system is similar to the original system with the following exceptions:

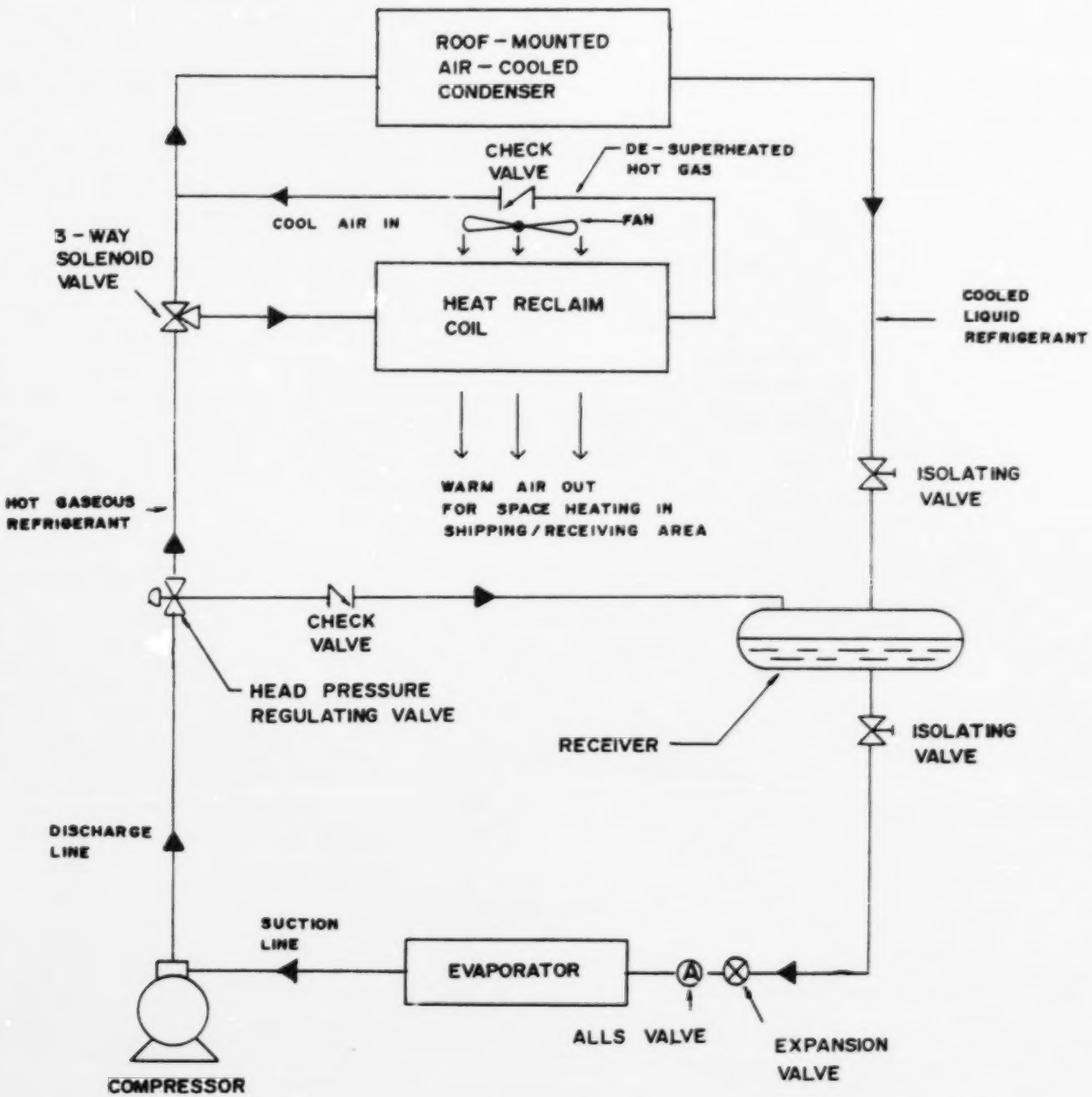
1. An air-cooled condenser, instead of water-cooled condensers, is used. Air instead of water is used for cooling in the condenser, resulting in savings in water costs.
2. A heat reclaim coil is connected into the refrigeration circuit through a 3-way valve whenever space heating is required. The heat reclaim coils are located indoor to heat the shipping and receiving area.

Referring to Figure 3, the operation of the modified system is as follows:

When heat is not required in the shipping and receiving area, the 3-way valve will shut off the passage of the hot gas refrigerant from the compressor to the heat reclaim coil. The hot gas refrigerant then by-passes the heat reclaim coil and flows directly to the condenser located on the roof of the building. Heat is then released to the outdoor air at the condenser. The gas refrigerant is condensed back to liquid and circulated back to the evaporator where it is allowed to expand and vaporize. This completes a "non-heating mode" refrigeration cycle.

When heat is required, the 3-way valve will route the hot gas refrigerant through the heat reclaim coil first before dis-

FIGURE 3. MODIFIED REFRIGERATION SYSTEM



charging the hot gas to the condenser. When the temperature of the coil reaches 38 degrees C., the fan of the heat reclaim unit will be turned "on", blowing air through the coil. The air heated by the heat reclaim coil is directed to the shipping and receiving area for space heating. Any excess heat in the hot gas refrigerant not required by the space heating is removed by the roof-mounted condenser. The liquid refrigerant leaving the condenser is circulated back to the evaporator. This completes a "heating mode" refrigeration cycle.

ECONOMIC ANALYSIS OF SYSTEM MODIFICATIONS

The cost to modify the refrigeration system is $16 565. This cost includes the two heat reclaim coils, a two-circuit air-cooled condenser and other associated material and labour. A detail breakdown of the cost is shown in Figure 4.

The savings achieved by the modifications to the system are from:

1. Reduction in space heating cost as a result of the heat supplied by the reclaim coils installed and
2. Reduction in water consumption as a result of replacing the two water-cooled condensers with a two-circuit air-cooled condenser.

Each heat reclaim coil is equipped with a built-in fan. The fans have air flow rates of 3650 and 3800 cfm. Measurements of air temperature entering and leaving these two heat reclaim coils indicated a temperature rise of 8 degrees C. and 13 degrees C. for the 3650 and 3800 cfm units respectively. These fans were observed to operate approximately 50% of the time. Based on the above information, the amount of heat available from both heat reclaim coils combined, for space heating during the heating season was estimated to be 335 million Btu. The savings on natural gas heating of the existing indirect fired unit heaters are thus about $2 100 per year. (See Table 2 for calculation of estimated energy savings.)

The total cooling capacity of the refrigeration system is estimated to be around 14.7 tons. The amount of water used by a water-cooled condenser is estimated to be about 0.75 U.S. gallons/minute/ton of cooling for a period of 20 hours a day. Thus, the amount of water used by the two water-cooled condensers was 4.8 million gallons per year or $5 200 per year at $0.81/100 cu. ft. of water.

The total savings in natural gas and water is $7 300 per year. The simple payback of the project is approximately 2.3 years. In addition to these savings, the new system also offers the following benefits:

1. Reduction in operation and maintenance costs, resulting from elimination of pressure regulating water valves and a lower head pressure.
2. Faster "pulldown" of temperature in refrigerated space i.e. it will take less time for the refrigerated space to reach the desired temperature.

The reduction in operation and maintenance cost will shorten the payback of the project. However, this figure will not be available until the modified system has been in operation for a period of time.

CONCLUSIONS AND RECOMMENDATIONS

The modified refrigeration system with heat reclaim units and air-cooled condensation was placed in operation successfully. Some preliminary measurements of temperatures were taken to estimate the heat available from the heat reclaim units and the savings in energy cost for space heating.

The reduction in water consumption resulting from the replacement of water-cooled condensers with an air-cooled condenser was estimated. Based on this information, this project shows a payback of 2.3 years.

This project has demonstrated that heat recovery techniques can be used to save energy in refrigeration system and conversion of water-cooled condenser to air-cooled condenser can save substantial water costs. However, the savings in water consumption has to be verified after the modified system has been in operation for a year.

The heat reclaim units at the Manco Dairy operate only when space heating is required in the shipping and receiving area. Therefore the waste heat available from the refrigeration system is not used for the majority of the time. To make use of all available waste heat, it is recommended that future heat reclaim units be designed to pre-heat domestic water during

periods of time when space heating is not required. Further monitoring of the refrigeration system at Manco Dairy and a follow-up report after a period of actual operations are also recommended.

TABLE 1

COST OF REFRIGERATION SYSTEM MODIFICATIONS

MATERIAL		
2	Heat Reclaim Coils	$ 2 150
1	Two-Circuit Air-Cooled Condenser	2 500
7	Alls Valves	1 750
1	Control Panel & Wiring	3 000
	Refrigeration Piping, Fittings, Pipe Insulation and Miscellaneous Material	2 500
	Sub-Total	$11 900
LABOUR		4 665
	TOTAL	$16 565

TABLE 2

CALCULATION OF ESTIMATED ENERGY SAVINGS

1. Heat Recovered By Heat Reclaim Coil From the R-502 Refrigerant

Air flow rate of fan = 3 650 cfm

Measured air temperature rise = 14 degrees F, or 8 degrees C

Heat recovered per hour = 3 650 x 1.08 x 14

= 55 188 Btu

2. Heat Recovered By Heat Reclaim Coil From the R-12 Refrigerant

Air flow rate of fan = 3 800 cfm

Measured air temperature rise = 24 degrees F, or 13 degrees C

Heat recovered per hour = 3 800 x 1.08 x 24

= 98 496 Btu

3. Estimated Energy Savings

Total heat recovered per hour from the refrigeration system

= 55 188 + 98 496 = 153 684 Btu

Assume a heating season of 26 weeks, and

from observation, the fan operates approximately 50% of the time, or 12 hours per day, then the energy saved per season

= 153 684 Btu/hr x 12 hrs/day x 7 days/wk x 26 wks/year

$= 335.64 \times 10^{6}$ Btu/year

Savings on natural gas heating by indirect-fired ceiling unit heaters $= 335.64 \times 10^{6}$ Btu/yr. x $5./$10^{6}$ Btu x 1/0.8(efficiency)

= $2 098 or by rounding = $2 100.

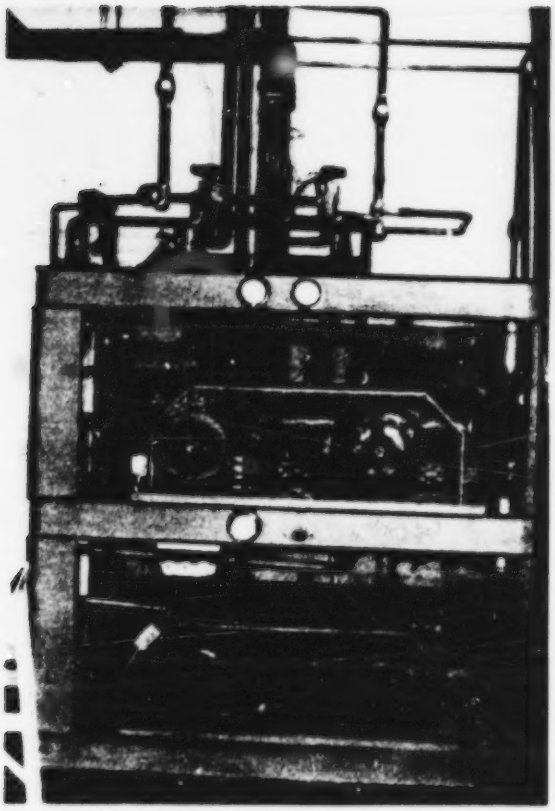


PHOTO I. COMPRESSOR

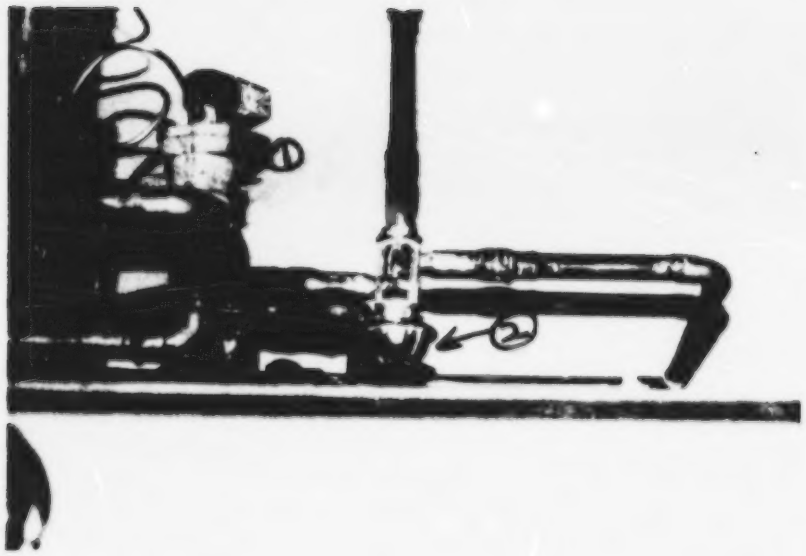


PHOTO 2. 3-WAY VALVE ① AND HEAD PRESSURE REGULATOR VALVE ②

HEAT RECLAIM UNIT

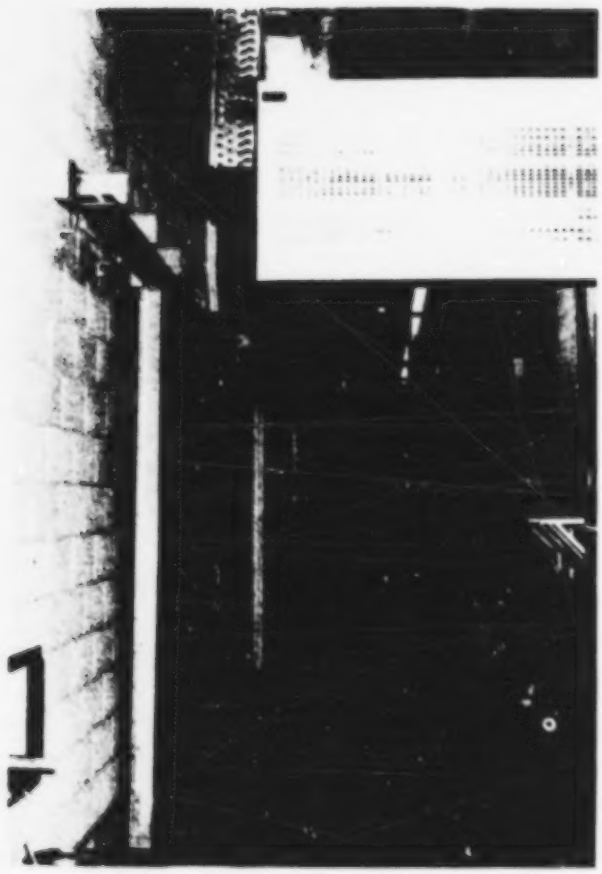


PHOTO 3. SHIPPING / RECEIVING AREA

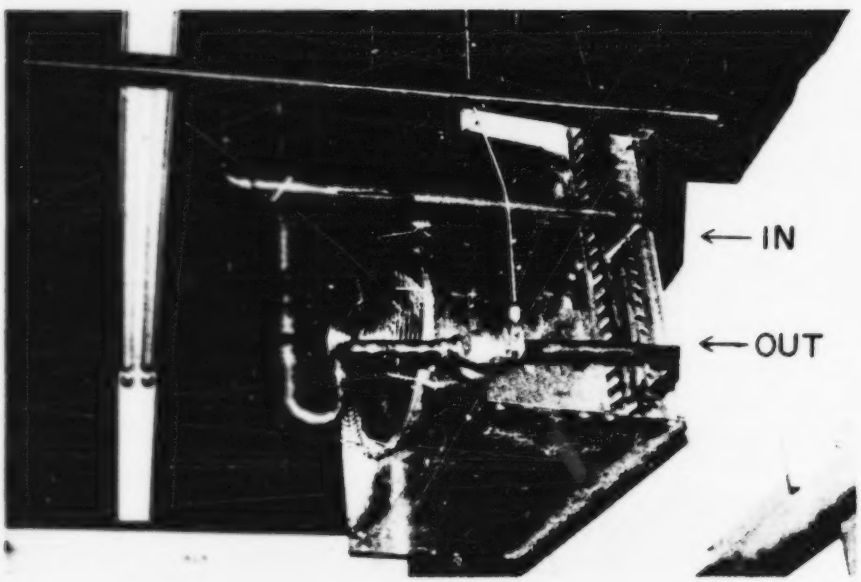


PHOTO 4. HEAT RECLAIM COIL AND FAN

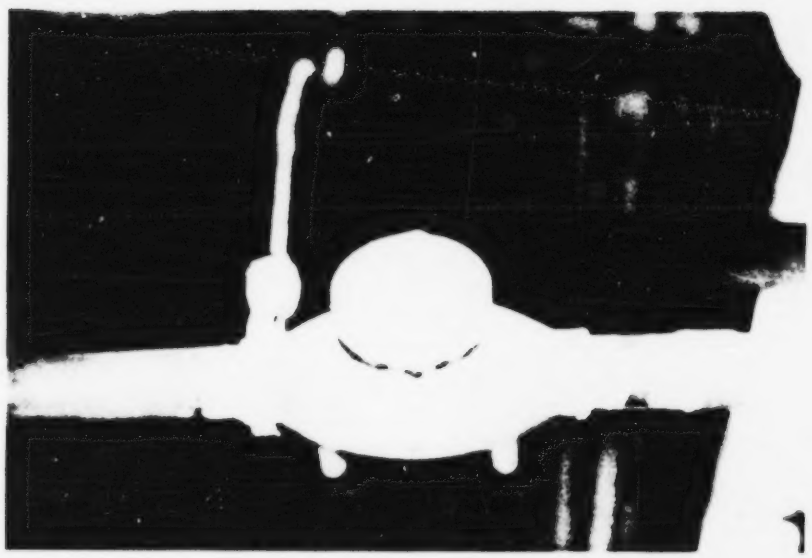


PHOTO 5. CHECK VALVE FOR HEAT RECLAIM UNIT

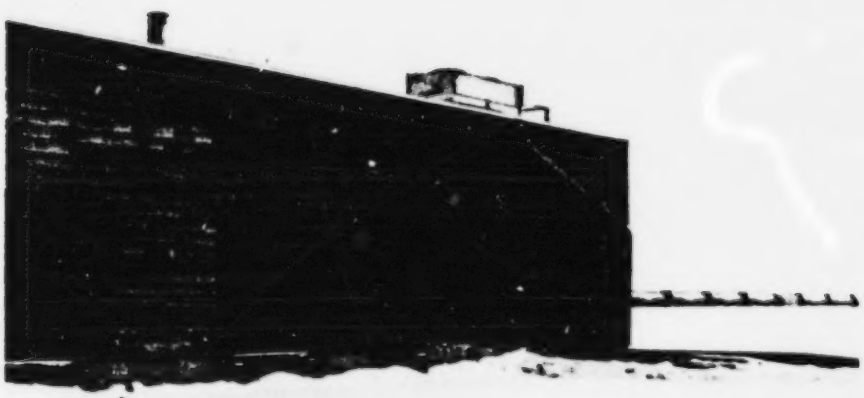


PHOTO 6. ROOF TOP AIR-COOLED CONDENSER